

# Development of Numerically Controlled Hydraulic Cushion System for Use in Deep Drawing of Sheet Metals

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## Abstract

It is well known, for many years, that deep drawability can be improved by applying variable blank holding force. To apply variable blank holding force during cup drawing, we set up pressure controlling system on experimental hydraulic press, and the pressure control system is often called NC(Numerically Controlled) cushion system. Using the NC cushion system we carry out pressure control experiment and the proposed structure shows good performance. And we compare drawability of square steel cups with NC cushion and that with conventional cushion. The results show drawability is greatly improved when the pressure control curve is designed in a S-shaped curve. This paper includes design details of the NC cushion system and experimental analysis of drawability with experimental NC cushion system.

## 1. Introduction

Deep drawing is a process that produces deep hollow cups without any joining. In Deep drawing process the center of metal sheet is drawn by a punch while rest of the material is restrained by binding pressure, which is often called as cushion force in sheet metal industries. Due to the friction between metal sheet and binder, the flow of metal is controlled to form a good cup shaped products. In conventional deep drawing, the restraining force, which is often called as BHF(blank holding force), is controlled by the time invariant pressure and the shape of the binder, on which some beads are installed to control restraining force. But it is well known, for many years, that if the blank holding force is applied as a function of the punch stroke, some beneficial effects can be found. The device that enables time varying cushion force is known as NC(Numerically Controlled) cushion system because it generates cushion force in a numerically controlled way. The most dominant effect of using NC cushion is that the deep drawing ratio, which is a measure of drawability, is greatly improved. This paper is concerned with the development of the NC cushion system on experimental 600 ton hydraulic press.

For this kind of cushion system, Hardt et al. investigated closed loop control system to control maximum stress and/or thickness of the simple

shape[1]. This is thought of the first research that control the blank holding force, even though the method is very different from the current, Thiruvurudchelvan also reported that the cups with less wrinkles can be produced by using blank holding force proportional to the punch force[2]. And Yoshihara et al. showed that fuzzy control can be applied to NC cushion pressure control[3] and Ujihara and Hirose also showed that the wrinkles in autobody panels can be suppressed by controlling blank holding force[4]. Ahmetoglu et. al reported that the wrinkling and fracture in deep drawing rectangular parts can be eliminated by the control of blank holding force[5]. Traversin et al. showed that controlling blank holding force can be beneficial effects through finite element simulations. And some researchers report that pulsating blank holding force, which can be implemented with NC cushion system, can improve drawability. Furthermore, some advanced researches regarding segment-elastic blank holder are also recently reported. In this paper, to implement NC cushion on industrial stamping press, basic design considerations on pressure control systems are investigated. And implementation of NC cushion and the experiments on drawability with it is described in detail.

## 2. Design of NC Cushion System

The two major advantages of using NC cushion is as follows.

1. Improved deep drawability: With same material and die designs, deeper products can be produced.
2. Noise reduction: This is achieved by reducing the impact velocity between upper die and lower die.

For the latter purpose, the speed of upper die should be high enough as in industrial press. But in this study, the only available press was experimental press with ram(upper die) speed is 2.4mm/sec. For this reason, research on the noise reduction is omitted inevitably. So this paper is focussed on the pressure control along with punch stroke, which is the main purpose of using NC cushion. The NC cushion system is mainly consisted of the following three